Strategic Policy Issues for DOE's Cleanup Program

ecisions about a series of broad policy issues could dramatically change the shape and cost of the Department of Energy's program to clean up the nuclear weapons facilities. Reexamining the goals and objectives of the program could result in a refocusing of cleanup efforts. The basic questions are what to do and when to do it. Should DOE try to eliminate all risks to human health and the environment, or is some risk accept-What should be done with the facilities-restore them for industrial, commercial, or residential use, or for recreation or other purposes? How fast can and should cleanup occur? Given the enormous cost of cleaning up the facilities and limited budgets for that purpose, what can DOE do to achieve the greatest benefits per dollar spent on cleanup?

Answers to these questions will affect the type, extent, and pace of cleanup. Given budgetary constraints, stretching out the cleanup program beyond the 30 years initially envisioned appears inevitable. DOE and its regulators will have to decide which objectives, types of problems, or sites to focus on first.

Information about risk to human health and the environment at DOE's nuclear weapons facilities is scant. Yet understanding these risks is crucial to making decisions about what remedial actions should be undertaken immediately, what should be done in the near future, and what would be desirable, if not essential, over the longer term. The discussion below suggests a need for substantial additional effort to identify and characterize risks from environmental contamination.

Intertwined with the goal of reducing risk are decisions about eventual land use at DOE sites. At

some, there is little choice. Sites where long-lived radioactive wastes have been disposed of will be off-limits to other uses permanently. Such sites could be fenced off permanently or until technologies are developed to allow detoxification. Plutonium, for example, remains hazardous for more than 25,000 years. Other areas also could be fenced off, at least until their value for alternative use becomes high enough to justify remediation. Still other sites might be made available for industrial use without cleaning them up to as high a standard as sites opened up for general use, provided that all the necessary precautions are taken to protect workers. Decisions about eventual land use will depend on both technical and economic feasibility as well as public preferences.

Efforts to reduce health, safety, and environmental risks and to restore lands to other uses will occur within the constraints of the federal budget. As discussed in Chapter 2, reliable estimates of cleanup costs are difficult to make but will inevitably be part of the process of determining goals and setting priorities. This chapter discusses the use of benefit-cost analysis as a way of determining which cleanup projects would offer the greatest benefits per dollar spent. It concludes with an example illustrating the trade-offs.

Background

In 1989, DOE announced the goal of completing environmental cleanup at the nuclear weapons facilities within 30 years. More recently the department has expressed the goal in terms of meeting all applicable legal requirements by 2019. Returning all DOE sites to a pristine state by 2019 is clearly not realistic, given the presence of such contaminants as long-lived radioactive materials and substances that persist in groundwater. Meeting legal requirements is also a challenge, especially where technologies are inadequate to achieve the prescribed level of cleanliness. Moreover, legal requirements may change over time, requiring DOE to meet increasingly strict standards.

Most people would agree that imminent hazards to the public should be eliminated promptly. DOE's program for corrective activities is intended to remedy such hazards. At Hanford, for example, one of DOE's top priorities is a storage tank containing a witches' brew of hazardous wastes that periodically releases hydrogen gas in concentrated amounts, raising fears of an explosion. Much of the environmental contamination at DOE facilities, however, does not appear to pose an imminent danger to the public. No one really knows the risks at the nuclear weapons facilities, but no strong evidence has been presented of imminent dangers that DOE is not attempting to resolve. Rather, there is a broad range of potential risks. For example, contaminants in the soil may be migrating toward underground aquifers, but at such a slow pace that reaching them would take many years.

Still other potential problems may pose fewer hazards if cleanup is delayed. Hanford's surplus reactors, for instance, contain a number of radioactive materials that decay over time. If DOE post-poned decontaminating and decommissioning these reactors for 75 years, half of the cobalt 60 would decay, significantly reducing potential exposure to workers.

Should DOE aim to eliminate all potential risks? Or to reduce them to some level that weighs costs against risks and is acceptable to the general public? Reaching consensus on this matter may be impos-

sible, but informed debate could contribute to a generally acceptable result.

Many people perceive hazardous waste sites to be extremely dangerous. Such well-publicized contaminated sites as Love Canal and Times Beach have raised public consciousness about hazardous wastes. Polls conducted by the Roper Organization in 1988 and 1990 reported high levels of public concern about Superfund and other hazardous waste sites.² This concern has been reflected in legislation authorizing environmental cleanup--in particular the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act--and in appropriations.³ Public perceptions have also been a driving force in the development of the cleanup agreements that DOE has signed with the Environmental Protection Agency and state agencies.

Reaching a consensus about the goals of environmental cleanup at DOE's nuclear weapons complex can be facilitated by discussion and debate that includes all interested parties. As the following sections suggest, however, experts, policymakers, and the general public all need more information than is now available to make informed judgments about goals and priorities.

Understanding Risks

How dangerous are DOE's nuclear weapons facilities? How much of a threat do they pose to health, safety, and the environment? How do risks from hazardous waste sites compare with risks associated with other environmental problems? The answers to these questions can help shape DOE's plans for cleaning up the hazardous waste sites.

In July 1993, workers installed a pump intended to agitate the liquid waste in the tank. They think the agitation will reduce pressure inside the tank by preventing the buildup of hydrogen and other gases. See *Inside Energy/with Federal Lands* (newsletter published by McGraw-Hill, Inc., New York, July 12, 1993), p. 6.

Environmental Protection Agency, Office of Policy, Planning, and Evaluation, "Environmental Problem Area Profiles" (July 20, 1991), pp. 7, 16.

In addition to DOE's program, the Department of Defense has a large and growing budget for cleaning up hazardous wastes, and the Superfund program now accounts for about one-quarter of EPA's budget.

The lack of comprehensive measures of risks from contamination at its facilities has hampered DOE's planning efforts. It has some information that was collected at various sites and by various offices within DOE, but the information has not been coordinated into a unified framework that would facilitate comparisons. As noted in Chapter 1, the Congress has directed DOE to evaluate risks to health and safety and to report on how they are to be addressed under the agreements DOE has entered into with the Environmental Protection Agency and state regulators. DOE has been directed to estimate risks based on the best scientific information available; it has not been asked to undertake the massive task of performing exhaustive formal risk assessments.4

In response, DOE has launched a risk management program whose objective is to bring together what is known about risks, identify the gaps in knowledge, and seek to fill them. (See Box 1 for a discussion of risk assessment and risk management.) To assist with this effort, DOE has asked the National Research Council of the National Academy of Sciences (NAS) to form a committee of experts to review DOE's risk management. NAS sponsored a workshop on November 3-4, 1993, for the committee to hear the views of facility managers, regulators, and stakeholders, and it issued a report on January 4, 1994.⁵

DOE says it has acted to remove all of the imminent threats that it knows about. The department recognizes that all sites do not pose equal threats to public health, safety, and the environment. For example, "a small, 'wet' site in a populated area may have the potential for higher risk due to the proximity of the community and the migration of contaminants than . . . contamination in the middle of a larger, 'dry' site that is far from populated areas."6 However, at the NAS workshop on risks, DOE's Assistant Secretary for Environmental Restoration and Waste Management acknowledged that the department had not yet identified the risks.

Until detailed investigations of each site have been completed, one can only draw inferences about potential risks on the basis of information from more general studies. Information about risks at hazardous waste sites in general may have important implications for DOE's problems.

Preliminary Assessments by ATSDR

The Agency for Toxic Substances and Disease Registry (ATSDR) has begun to assess public health risks associated with DOE facilities.7 It has completed a preliminary survey of 19 DOE sites and has categorized them by potential public health risks.8 The rankings are preliminary but will aid ATSDR in developing plans for in-depth studies of potential public health problems. Over the next several years, ATSDR will compile and analyze data on exposure to hazardous substances at DOE sites. It will then assess current and likely future impacts on human health from the release of hazardous substances into the environment.

In ATSDR's initial screening, only Hanford was included in the highest potential risk category, defined as "sites where exposure is known to be occurring or has occurred at levels of contamination that might cause acute health effects."9 Fernald, Los

U.S. House of Representatives, Making Appropriations for Energy and Water Development for the Fiscal Year Ending September 30, 1994, and for Other Purposes, Conference Report 103-305, to accompany H.R. 2445 (October 22, 1993), pp. 94-95.

National Research Council, Building Consensus Through Risk Assessment and Management of the Department of Energy's Environmental Remediation Program (Washington, D.C.: National Academy Press, 1994).

Department of Energy, Environmental Restoration and Waste Management Five-Year Plan, Fiscal Years 1994-1998, vol. 1 (January 1993), p. v.

Section 104(i) of CERCLA created the ATSDR within the Public Health Service to study health effects of toxic substances.

^{8.} Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Division of Health Assessment and Consultation, Federal Programs Branch, Health Assessment Activities at Department of Energy National Priorities List Sites for FY 1992 (November 1992). The sites include 16 DOE sites on the National Priorities List (NPL), one proposed for the NPL, one jointly listed as a DOE/Army site, and one for which ATSDR received a petition for assessment.

^{9.} Ibid., p. 9. ATSDR considered Hanford areas 100, 200, 300, and 1100 separately; it put the 100, 200, and 300 areas in the highest risk category.

Box 1. Risk Assessment and Risk Management

Risk assessment and risk management are commonly confused. Indeed, the terms were sometimes used interchangeably at the risk-management workshop convened by the National Academy of Sciences on November 3-4, 1993. Risk assessment generally includes the development and analysis of scientific information; it is an input--but not the only input--to risk-management decisions. Risk management consists of actions that are intended to alter the likelihood of certain events or outcomes.

A risk assessment is based on detailed scientific analysis. It involves identifying substances that may be hazardous to human health and determining their effects on health. In many cases, the latter entails exposing laboratory animals to very large doses of the substance, measuring the effects, and then interpreting the implications of smaller exposures for humans. A risk assessment may estimate the number of people who might be exposed to a harmful substance and the length and type of exposure. The product of a risk assessment is usually a measure of additional risk, such as one additional cancer case over 20 years among 10,000 people living within a given distance of the hazard.

But in many respects, risk assessment is an art, not a science. The assessor rarely has complete information about every aspect; the art includes a judgment about what can safely be left out of detailed analysis. Lacking sufficient information about key elements of the analysis, the assessor may have to make numerous assumptions in order to proceed. How uncertainty about the assumptions is handled can have an impact on the results. Stating clearly these assumptions can enhance the credibility of a risk assessment and can facilitate testing the sensitivity of the results.

People not trained in science may be able to provide information that would improve the reliability and the credibility of risk assessments by augmenting the work of scientists. For instance, a risk assessment may assume that a certain number of people live within a certain radius of a contaminated site for a certain number of years. But the local community may disagree with the assumptions and present evidence that many people live there for longer than assumed, or that the community is growing and more people are moving into the area where they might be exposed to contaminants. A risk assessment should be presented in such a way that these alternative assumptions can be factored in, to see what their effect is on the resulting estimate of risk.

Risk assessments also may make assumptions about the amounts of various foods people eat. If some ethnic groups consume much larger amounts of fish, in which contaminants bioaccumulate, relative to other sources of protein, the potential risk may be underestimated. Managing risk involves combining the results of risk assessments and many other factors to determine an appropriate set of actions. These other factors may include competing demands on the resources available to reduce risks, the availability of technological remedies, and comparisons with other risks. For example, one might want to compare the risks existing at a site with the risks of remediation. The latter particularly affect workers--those engaged at the site in current activities (for example, monitoring or maintenance) and those who would perform cleanup tasks. Digging up contaminants that have been contained poses additional risks, as does transporting them to storage and disposal facilities. Transporting contaminants off-site may be especially hazardous, since DOE cannot control safety on the highways or railroads.

Managing risks involves a number of thorny issues. Among them are:

- How to compare risks that are voluntary (skydiving) with those that are involuntary (living in an area with poor air quality);
- How to factor in effects on the most susceptible members of the exposed population when those effects greatly exceed the effects on the average person;
- How to account for large differences in expected exposure (for example, if most people living near a hazard stay there only a few years but some spend a lifetime there);
- How to deal with risks that are very large but affect only a small number of people living near a site;
- How to treat risks that affect various age groups or other population groups differently; and
- o How to compare scientific studies whose results differ (for example, somehow "average" the results, place the greatest weight on the most pessimistic, take what the majority of "experts" conclude, and so on).

There are no easy answers in evaluating and managing risks. But the presence of subjectivity does not mean that risk assessments are not useful nor that consensus about managing risks is unattainable. If estimated risks from different environmental problems vary by orders of magnitude, for example, it may be clear which ones to pursue first. Where risks appear high in some studies but not in others, additional research may be an important element of risk management. And public debate on the most difficult issues that involve individual and societal values can provide useful information for officials as they set policies for managing risks.

Alamos National Laboratory, Oak Ridge, and Hanford's 1100 area were included in the second highest risk category, defined as sites where exposure is probable, chronic health effects are possible, and/or residents have alleged that health effects have occurred. Rocky Flats and Savannah River were put in the third category--sites for which there is limited information and where available information indicates exposure is occurring or has occurred --but will be subject to additional review. Idaho National Engineering Laboratory was put in a fourth category of sites for which limited information indicates that exposure is not occurring. ATSDR surveyed other DOE sites as well, but the sites listed above are the ones with the most environmental cleanup activity.

ATSDR emphasizes that its categorization is preliminary and may change as additional information becomes available. The categories do not represent conclusions about public health risks.

EPA Studies of Risks

The Environmental Protection Agency has published two reports about the risk associated with hazardous waste sites compared with other kinds of environmental problems. The reports are by no means conclusive, nor do they purport to be. They recognize that the state of knowledge about a broad range of environmental risks is still in its infancy. 10 Still, they provide a comprehensive overview of the relative risks of various environmental problems, in the judgment of experts. The reports discuss in detail the importance of understanding how different environmental threats--such as pesticide residues in food, automobile emissions, and leaking drums of hazardous wastes--pose risks to human health, human welfare, and ecology.11

The EPA reports reach the surprising conclusion--at least in view of common perceptions--that hazardous waste sites rank considerably lower in risk than many other environmental problems. Although the DOE facilities may have special problems that would make them rank higher than other hazardous waste sites, the EPA studies indicate that other types of environmental problems pose greater risks to health and safety than do waste sites in general.12

The first report, Unfinished Business, contains assessments by EPA experts of risks associated with a variety of environmental problems.¹³ The report drew on the expertise of health scientists, engineers, economists, and other specialists in environmental programs administered by EPA. The experts formed four groups, each focusing on one of four major categories of risks: cancer risks, noncancer health risks, ecological risks, and welfare risks. Each group of experts compared risks across the full range of environmental programs--clean air, clean water, toxic substances, pesticides, radiation, solid wastes, hazardous substances, and so on--and ranked risks from environmental problems as relatively high, medium, or low.¹⁴

Because most of DOE's environmental cleanup involves hazardous waste sites--active and inactive-the experts' rankings are useful in providing a sense of the relative threat that each site poses to public health and the environment. The rankings are by no means conclusive, however. Additional specific

^{10.} Risk assessment is a complicated undertaking, involving an understanding of a variety of disciplines, including toxicology, epidemiology, and statistics. For a summary of issues surrounding risk assessment, see the Carnegie Commission on Science, Technology, and Government, Risk and the Environment: Improving Regulatory Decision Making (New York: Carnegie Commission, June 1993), especially pp. 76-78.

^{11.} EPA included in "welfare effects" such effects as damage to property and groundwater supplies, aesthetic losses, and loss of recreational benefits.

^{12.} A motivation for the EPA studies was to help set priorities in environmental policy. DOE is more constrained than EPA, having to adhere to EPA rules, triparty agreements, and laws and regulations set by other regulatory agencies.

^{13.} Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Unfinished Business: A Comparative Assessment of Environmental Problems (February 1987). As the title suggests, the risks addressed by EPA are those remaining; many potential risks have already been removed or abated through controls in place under existing laws and regulations.

^{14.} The groups took slightly different approaches in structuring their ranking systems. The experts assessing cancer risks and welfare risks ranked the environmental problems separately and then grouped them into clusters of relatively high, medium, and low risks. The experts assessing noncancer health risks and ecological risks presented their findings in clusters reflecting degree of relative risk but did not rank individual environmental problems separately.

information about risks at individual sites would be required to establish a more definitive ranking.

Cancer Risks. EPA's experts on cancer risks ranked inactive hazardous waste sites eighth highest of the 29 environmental problems studied, and active sites 13th. These individual rankings put hazardous waste sites in the second riskiest group of cancer-risk problems. The experts considered inactive hazardous waste sites to be less of a threat than the exposure of workers to chemicals, indoor radon, pesticide residues on foods, indoor air pollutants other than radon, exposure of consumers to chemicals, hazardous and toxic air pollutants, and depletion of stratospheric ozone.¹⁵

Noncancer Health Risks. EPA's experts on noncancer risks to human health rated both active and inactive hazardous waste sites relatively low on the risk scale.¹⁶ A major reason for the low ranking is that despite the moderate toxicity of substances at hazardous waste sites, relatively few people are exposed, and exposures are generally by indirect routes and low in concentration. These characteristics contrast with problems rated as a higher risk, such as air pollutants, pesticides, and discharges to sources of drinking water and water habitats of edible fish and shellfish.¹⁷ Exposure of a small number of people, of course, does not mean that a hazard can be ignored. It may have a bearing, however, on the best way to reduce or eliminate a risk. Even though lack of hard scientific data led the work group on noncancer health risks to rely heavily on professional judgment, there was a surprising amount of consensus about the rankings.

Although the experts did not consider the health risks at hazardous waste sites to be high, they noted that if hazardous substances at these sites are not contained--if they seep into groundwater, for instance, or pollute the air--the risks may be much higher. Risks also may be high for workers at the sites. These factors may raise the relative threat to health at some DOE facilities.

Ecological Risks. The ecology experts considered risks of damage to entire ecological systems, to geographical regions, and to the biosphere itself. They ranked active hazardous waste sites in the lowest of six risk groups, and inactive hazardous waste sites in the second lowest group. The primary reason given for the relatively low ranking is that environmental problems caused by hazardous waste sites generally are highly localized. Moreover, even the local environmental impacts typically are low. The experts noted, however, that the rankings of ecological risks of Superfund sites must be considered tentative because they are based on relatively little data. 19

Welfare Risks. EPA's experts on welfare risks considered how environmental problems reduce the value of a variety of goods, services, and activities. They reported two types of risks: to community drinking water supplies, and to property values of nearby residences. Examples of welfare effects include damage to property by air and water pollutants, diminished enjoyment of natural resources because of pollution, and lower yields from farming and fishing. Of the 23 environmental problems ranked, inactive hazardous waste sites were ranked ninth, and active hazardous waste sites were ranked 11th. Like the ecological risk group, the welfare risk group downgraded the risks of waste sites because "most of their effects are localized, and most waste sites are located away from areas of high population density."20

Environmental Protection Agency, Unfinished Business, Appendix I, "Report of the Cancer Risk Work Group," Table 1, pp. 4-10.

^{16.} Ibid., Appendix II, "Report of the Non-Cancer Risk Work Group," Table 2-1, p. 2-2. Because of uncertainties and lack of data, the noncancer work group did not numerically rank each type of environmental problem (although they used a quantitative scoring system to help in the ranking process). Instead, they used three categories of risk: low, medium, and high.

^{17.} Ibid., p. 2-3. Municipal and industrial nonhazardous waste sites were ranked in the medium-risk category (Table 2-1, p. 2-2). The experts considered them riskier than hazardous waste sites because larger numbers of people were potentially exposed to pollutants, and in the case of industrial sites, exposure concentrations were expected to be higher (Table 2-2, p. 2-7).

^{18.} Ibid., Overview, pp. 48-49.

^{19.} Ibid., Appendix III, "Basis for Ranking Position."

Ibid., Appendix IV, "Report of the Welfare Risk Work Group," p. 7-10.

Criticisms and Follow-up to EPA's Unfinished Business

EPA's Unfinished Business represented a major step in systematically examining risks and comparing different kinds of threats to human safety, health, welfare, and ecology. The EPA Administrator subsequently asked EPA's Science Advisory Board (SAB) to review the report, "to examine strategies for reducing major risks, and to recommend improved methodologies for assessing and comparing risks and risk reduction options in the future."21 Building on the report's findings that the activities and media regulated by EPA presented substantially different risks, the SAB noted the lack of coordination among environmental laws and programs. It recommended measures to integrate environmental policies so as to make use of risk comparisons in setting priorities among policy actions.

The SAB found several shortcomings in *Unfinished Business*, most of which were attributed to the limited information available about risks and other relevant factors. The SAB also expressed concern that the report defined some environmental problems so broadly as to encompass all gradations of risks--thus making assignment to a single risk group meaningless. The SAB noted that the environmental problems identified in *Unfinished Business* were an amalgamation of noncomparable items, including specific pollutants, sources of pollutants, and types of exposure.

Still, the SAB did not dispute the report's rankings of relative health risks. Instead of reassessing health risks, the SAB's Human Health Subcommittee devoted its efforts to seeking ways of resolving a variety of methodological problems. For example, the subcommittee noted the desirability of developing an aggregate ranking that would combine the relative risks of cancer and noncancer health effects.

It also recommended stepped-up efforts to gain information about the health effects of various types and amounts of exposure to various substances.²² Until better scientific information becomes available, the health subcommittee deemed it "not illogical" to rank as most risky the environmental problem areas with the highest probability of exposing humans to toxic substances--in effect, the problem areas classified as highest risk in *Unfinished Business*.²³

For nonhealth risks, the SAB's assessment differed somewhat from that of *Unfinished Business*. The SAB's Ecology and Welfare Subcommittee recommended moving active hazardous waste sites up one risk category from the lowest to the second lowest category and moving inactive hazardous waste sites to a medium-risk category. The subcommittee questioned *Unfinished Business*'s assumptions that current regulation is adequate to deal with all potential threats of migration of contaminants from waste sites. It also expressed concern about release of toxic substances from inactive hazardous waste sites and recommended continued monitoring of such sites.²⁴

The SAB noted the dichotomy between the public's perceptions of risk and the risk assessments of environmental professionals. Given the nature of the political process, the problems the public perceives to be serious have received greater attention in environmental legislation, regulation, and budgets than have problems deemed serious by experts. This dichotomy probably also applies to the DOE cleanup program: the public appears to be greatly concerned about hazardous wastes, even when they are properly stored and considered by experts to pose relatively little threat to health, safety, or the environment (the limited information available about actual risks at each site, however, precludes a definitive assessment). The SAB recommended improving the public's understanding of environmental risks.

Environmental Protection Agency, Science Advisory Board, Reducing Risk: Setting Priorities and Strategies for Environmental Protection, SAB-EC-90-021 (September 1990), p. ii (cover letter from SAB Chair Raymond Loehr and Co-Chair of Relative Risk Reduction Strategies Committee Jonathan Lash to EPA Administrator William K. Reilly).

^{22.} Ibid., Appendix B, pp. 7-8.

^{23.} Ibid., p. 93.

^{24.} Ibid., Appendix A, pp. 50-53.

Conclusion

Much work remains to be done in assessing health, safety, and environmental risks. Understanding the risks at DOE's nuclear facilities--as well as those from other environmental problems--is essential for directing resources to where they buy the most protection from risks. Responsibility for studying these risks does not necessarily lie with DOE, however. Such agencies as EPA and ATSDR most likely have a comparative advantage in conducting risk assessments because protecting the public from health and environmental risks is central to their The National Academy of Sciences' missions. effort to advise DOE on risk assessment and risk management should make a valuable contribution to understanding risks.

Weighing Benefits and Costs

Risk assessment in its current state has many short-comings. What role, then, can it play in formulating public policy? Although in some instances the uncertainties are so great that even trying to rank relative risks is fraught with peril, the findings of risk assessments can help inform the debate on how to proceed with hazardous waste sites. Nonetheless, extremely difficult choices remain to be determined by the political process, guided by informed public opinion. How does society value preserving an ecological resource? Is a given reduction in risk of cancer today more valuable than the same reduction in risk 50 years hence? What about one cancer case today versus 10 cases in 100 years?

If resources to reduce risks were unlimited, setting priorities would not be a problem. But choosing to spend cleanup money to address certain environmental problems has the opportunity cost of not addressing others that may pose bigger risks. How do the threats of DOE's environmental problems compare with others? What criteria could be used to help decide how much should be spent on cleaning up DOE facilities? How can the nation get the maximum benefit for the money spent on environmental cleanup?

Risks and Resources

The amounts of resources the federal government is devoting to environmental problems do not closely parallel the risks as assessed by the experts. For example, EPA's experts considered risks to human health from indoor air pollutants (including radon, asbestos, and other pollutants) to be high; in contrast, a Roper poll found public concern about indoor air pollutants to be low. EPA's budget in 1992 included just \$28 million for indoor radon and \$32 million for other indoor air pollutants. In comparison, EPA's Superfund budget was more than \$1.7 billion, the environmental restoration component of DOE's cleanup budget (the part most like Superfund) was \$1.1 billion, and the entire DOE cleanup budget was \$4.4 billion.

These numbers do not necessarily indicate that the federal government is spending the wrong amount on these problems; that conclusion would require at least two types of additional information. First is the matter of the appropriate role of the federal government in reducing environmental risks. In some cases, such as radon in homes, the appropriate federal role may be to make people aware of a potential problem but to leave testing and mitigation to the homeowner. For many environmental problems, the federal government requires companies to reduce pollution using their own resources. For the DOE complex, however, the environmental responsibility clearly rests with the federal government.

The other type of additional information needed concerns the benefits to be gained from spending on environmental problems. Ideally, the federal environmental budget would be allocated so as to achieve the greatest benefits per dollar spent.

Risk Trade-offs

If reducing existing risks is a primary goal of environmental cleanup programs, then it also is important to avoid increasing risks when carrying out cleanup activities. Some environmental cleanup actions present their own set of increased risks. In some cases, for example, excavating and burning

soil to rid it of contaminants may cause releases of hazardous air pollutants. Transporting wastes from dispersed sites to a central disposal facility carries with it risks of accidental release of hazardous materials.25 Thus, unless hazardous substances are leaking or otherwise migrating into the environment, it may be safer to leave them where they are. And it may be safer to contain spills or leakages than to take more active measures to remove or destroy pollutants.

Using Benefit-Cost Analysis

Because environmental cleanup places large demands on limited resources, cleanup dollars must be spent as effectively as possible. That can be accomplished by comparing the benefits and costs of alternative plans to see which is likely to yield the largest net benefits.

Benefits of environmental cleanup include reducing risks to human life and health, mitigating harmful effects on plants and animals, improving the quality of the environment, maintaining biodiversity, and so on. Measuring--or even completely identifying--these benefits presents significant challenges because of the many uncertainties about the way hazardous wastes migrate into the environment and affect the health or welfare of humans and other living things. Consequently, attempts to quantify the benefits from reducing exposure to risks should make clear the uncertainties attached to them.

Once benefits have been identified, they must be evaluated; that is, what value do people place on them? Estimating values of benefits is not easy because no active market exists for many types of benefits. Perhaps the most difficult challenge is figuring what value to place on reducing the risk of premature death. One method is to observe what people are willing to pay, or give up, to reduce risks, such as equipping their cars with antilock brakes or installing smoke detectors in their houses. The offering of higher wages to get workers to accept dangerous jobs provides additional evidence about how people value risks.²⁶ The federal government implicitly places values on risk reduction in the regulations it issues. The estimated cost per premature death averted ranges from \$100,000 to more than \$5.7 trillion (see Table 3).

Placing a value on natural resources is also difficult. For some lands, private market transactions enable comparisons. For instance, the value of a DOE facility offered for industrial use could be determined by the amount that businesses are paying for comparable facilities. But it is harder to estimate how much people are willing to pay for restoring a site to its pristine condition. Some evidence can be derived from observing how much people are willing to spend on national parks or for recreational resorts. Additional information can be gained from surveys in which people have been asked how much they would be willing to pay for a variety of attributes of environmental quality.²⁷

One can sometimes get around the problem of placing a direct value on potential benefits by instead comparing the cost-effectiveness of alternative policies to environmental cleanup. This approach is based on how much can be achieved (in terms of risks reduced, or any other objective) per dollar spent. Alternative policies can then be compared in terms of the benefits they produce. Cost-effectiveness is likely to vary greatly among sites and among the types of waste to be cleaned up.²⁸

^{25.} See, for example, Department of Energy, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, Draft Environmental Impact Statement, DOE/EIS-0119D (March 1989), p. 3.51.

^{26.} Economists have written many books and articles on this subject. For a recent reference, see Kip W. Viscusi, Fatal Tradeoffs: Public and Private Responsibilities for Risk (New York: Oxford University Press, 1992).

^{27.} These surveys are known as "contingent valuation" studies in the economics literature. For a more complete discussion, see A. Myrick Freeman III, The Measurement of Environmental and Resource Values: Theory and Methods (Washington, D.C.: Resources for the Future, 1993).

^{28.} Cost-effectiveness analysis can also be used to compare options for meeting a narrower set of objectives. Examples include finding the least-cost method of reaching a given regulatory standard or the least-cost method of treating a given volume of waste.